

United Space Alliance, LLC Materials & Process Engineering

Chrome - Free Aluminum Coating System

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Government Agency Policy on Hexavalent Chromium

- **OSHA has identified hexavalent chromium as a cause of serious, acute, and chronic exposure hazards for personnel**
- **EPA restrictions on airborne and liquid release of chromium containing compounds**
- **The Under Secretary of Defense issued a Memorandum in November 2008 entitled “Minimizing the Use of Hexavalent Chromium”, which directed DoD Military Departments to:**
 - “Approve use of alternatives where they can perform adequately for the intended application and operating environment”
 - “Update all relevant technical documents and specifications to authorize use of the qualified alternatives and therefore eliminate the use of materials containing Cr⁺⁶”

Aerospace Aluminum Alloys

- **Aerospace aluminum alloys used in missiles and aircraft are typically wrought products of the 2xxx, 7xxx, and 6xxx series, in various precipitation hardened tempers**
- **These grades of aluminum are chosen for their light weight and high strengths, but require supplemental corrosion protection methods to maximize the service life**
- **Aerospace aluminum alloys have traditionally used hexavalent chromium compounds (Cr^{+6}) to mitigate corrosion**
 - These compounds have been the preferred protection method for aerospace aluminum alloys
 - These compounds have been used for over 50 years

Coating History at United Space Alliance

- Solid Rocket Booster (SRB) structural hardware is constructed primarily of 2219-T87
- From the beginning of the Space Shuttle Program through the mid-1990's, the SRB hardware was coated with chromate - containing Alodine® 1201™ pretreatment, and AKZO epoxy topcoats which contained lead and chromates
- To achieve the maximum levels of corrosion protection, all aluminum alloys used for SRB hardware have utilized a 3-part system comprised of:
 - Conversion Pretreatment
 - Primer
 - Topcoat

Coating History at United Space Alliance

- **During the mid-1990's the SRB coating systems for aluminum alloys were changed to:**
 - Alodine® 1201™ hexavalent chrome conversion pretreatment
 - Deft chromated water-borne epoxy primer (lead - free)
 - Deft urethane topcoat (lead - free)
- **In 1999, USA began an extensive test program to qualify chrome - free pretreatment and coating systems**
 - 40 systems were evaluated
 - Alodine® 5200™ and 5700™ pretreatment, in combination with chrome - free primer and topcoat, proved to provide the best corrosion protection
 - **Performance criteria included**
 - Adhesion
 - Corrosion Resistance (Oceanfront Atmosphere, Seawater Immersion, Salt Fog, Electrochemical Impedance Spectroscopy)
 - Service Environment and Service Life
 - Future Processing (Touch-Up, Repair, Recoat)
 - Compatibility with Thermal Protection Coatings

Chrome - Free Replacement Testing

- **The Alodine® Deft Replacement project consisted of three phases**
 - Down selection
 - Qualification
 - Implementation
- **Down selection consisted of:**
 - 40 suppliers evaluated
 - Phase I Testing - Six pretreatments and six coating systems
 - Phase II Testing - Three pretreatments and three coating systems were chosen for qualification
- **Qualification testing consisted of over 4,000 tests:**
 - All coating candidates were tested with each pretreatment candidate and the corresponding baseline
 - Testing was halted for candidates that were found to be unsatisfactory
 - Processability (Personnel Considerations, Repeatability)

Chrome - Free Replacement Implementation

- **Implementation consisted of:**
 - Validation on Flight Structures (process validation - not flown)
 - No processing anomalies
 - Meeting acceptance requirements
 - Processing engineering change paper to incorporate change into engineering drawings and procedures
 - Verification on flight structures (flown)
 - Life Cycle Monitoring
 - Surface mapping for pits and general corrosion
 - Continuing to gather performance data

Chrome - Free Processing

- **After this extensive three year evaluation, USA converted to chromate - free pretreatment and primer in 2002 for processing SRB hardware for the Space Shuttle Program**
- **USA's testing showed that moving away from Cr^{+6} , while meeting baseline corrosion protection performance requirements**
 - Requires a system, as opposed to individual components
 - Maximum corrosion protection requires pretreatment, primer, and topcoat
- **SRB hardware has been flying for the past 7 years using chrome - free systems, with no deleterious effects**

Chrome - Free Processing (cont.)

- **The chrome - free pretreatment and primer / topcoat systems are being targeted for use on future manned space flight vehicles**
- **As a result of USA's proactive approach to finding an environmentally friendly solution to mitigate the hexavalent chrome issue on SRB hardware**
 - USA has become a recognized leader within the aerospace community in the removal of Cr^{+6} from coating waste streams
 - USA is the only aerospace company at Kennedy Space Center to be using chrome - free conversion pretreatment and primer for flight hardware

Chrome - Free Coating System

- **Current Coating System Used on SRB Hardware**
 - **Chromate - Free Pretreatment System**
 - Chosen through testing as the primary conversion pretreatment on SRB aluminum hardware due to:
 - Chromate - free
 - Can be disposed of as non-hazardous waste
 - Alodine® 5200™ (immersion tank application) and Alodine® 5700™ (brush and spray application)
 - Operational personnel prefer this system due to ease of application and reduced exposure to hazardous material

Chrome - Free Coating System (cont.)

- **Current Coating System Used on SRB Hardware**
 - **Chromate - Free Primer and Topcoat System**
 - Chrome - free primer and topcoat were chosen through testing as the primary coating system for aluminum SRB hardware due to
 - Ease of mixing
 - Non-hazardous disposal
 - Ease of application (8 hour pot life for both primer and topcoat)
 - Operational personnel prefer this system due to reduced exposure to hazardous wastes and extended working life

Acreage Coverage of SRB Components

- **SRB Aft Skirt coated with Alodine® 5700™ and chrome - free primer / topcoat protective finish**



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Acreage Coverage of SRB Components

- SRB forward structures coated with Alodine® 5700™ and chrome - free primer / topcoat protective finish



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Benefits of Chrome - Free Coatings

- **Benefits of Chromate - Free Pretreatment Systems**
 - Conforms to EPA and OSHA guidelines concerning hexavalent chromium
 - Supports the new DoD directive concerning the reduction of hexavalent chrome
 - Reduces in-process costs due to handling / safety issues
 - Reduces disposal costs
 - Meets or exceeds corrosion protection (as a system) compared to hexavalent chromium systems

- **Benefits of Chromate - Free Primer Systems**
 - Removes chrome compounds from processing stream
 - Meets or exceeds performance, repeatability, and adhesion as compared to chromate baseline coating systems
 - Provides corrosion protection foundation for polyurethane topcoats

Why is USA's Chrome - Free Coating System a Good Solution?

- Eliminates chromates from waste processing streams
- Reduces worker exposure to hazardous materials
- Pretreatment satisfies baseline adhesion properties for primers and adhesives
- Pretreatment with paint systems satisfies corrosion resistance baseline requirements
- Pretreatment has an extended window for primer application
- Pretreatment is compatible with all SRB coating systems
- Pretreatment may be applied to all aluminum surfaces

Next Generation of Pretreatments

- **After 7 years of chrome-free processing, USA is evaluating new chrome - free coatings for aerospace use**
- **Electrodeposited Inorganic Titanium Oxides show promise as the next generation of chromate - free pretreatment**
 - This product is deposited by cool plasma
 - Deposit applied to aluminum and titanium alloys, and aluminized iron-base substrates
 - Corrosion resistant
 - Provides substrate corrosion protection
 - Wear resistant
 - High heat resistance
 - Chemical resistance
 - Coating thickness of several microns
 - Foundation for topcoats, adhesives, or thermal protection systems
 - May eliminate the need for organic topcoats